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**Rocky Mountain
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Experiment Station**

Fort Collins,
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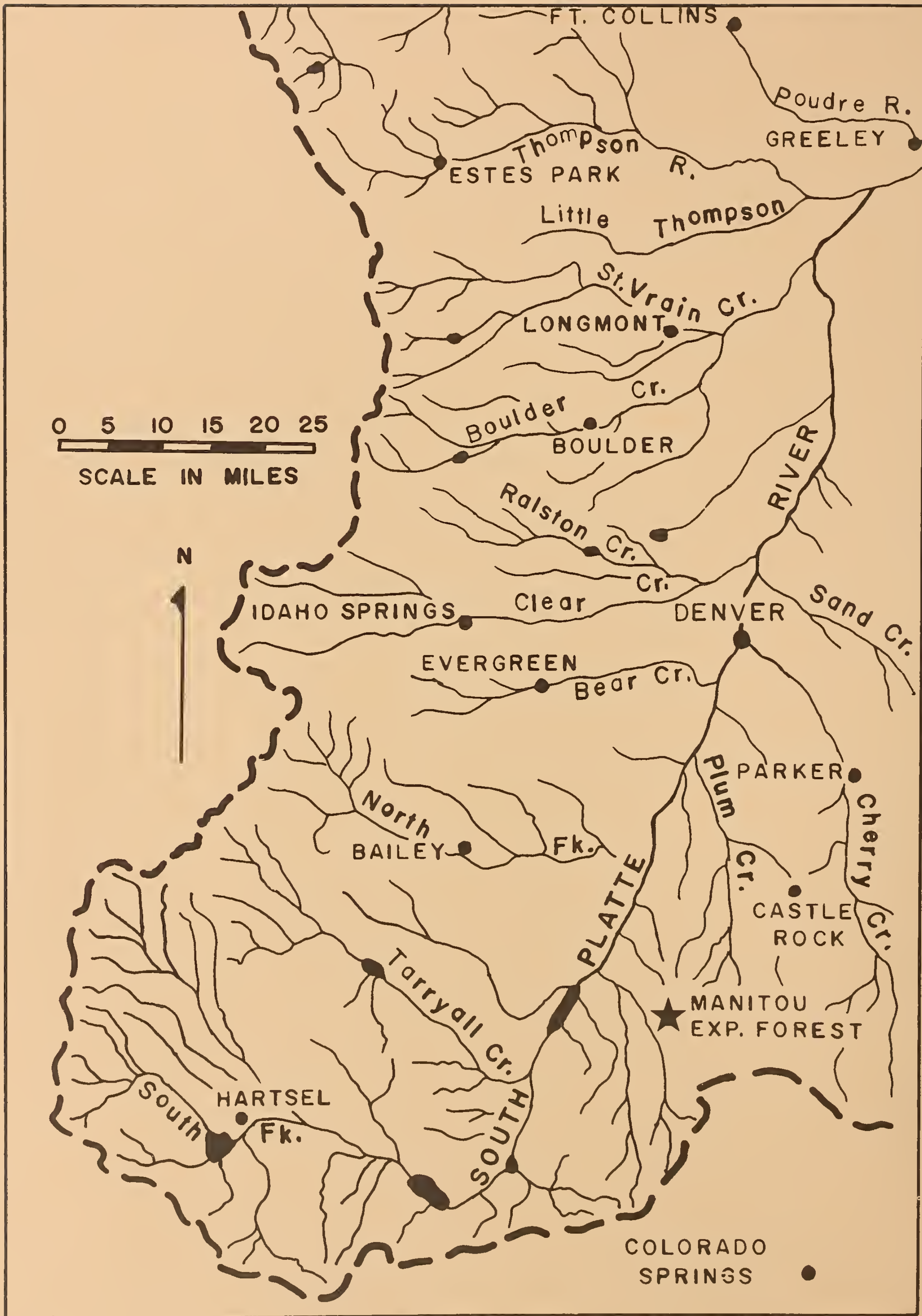
**General Technical
Report RM-116**

# A Summary of Research at The Manitou Experimental Forest in Colorado, 1937 – 1983

Howard L. Gary



FT. COLLINS
Poudre R.
GREELEY
Thompson R.
ESTES PARK
Little Thompson
St. Vrain Cr.
LONGMONT
Boulder Cr.
BOULDER
0 5 10 15 20 25
SCALE IN MILES
N
Ralston Cr.
RIVER
Clear Cr.
IDAHO SPRINGS
DENVER
Sand Cr.
EVERGREEN
Bear Cr.
PARKER
Plum Cr.
Cherry Cr.
North Fk.
BAILEY
PLATTE
CASTLE ROCK
Tarryall Cr.
MANITOU EXP. FOREST
South Fk.
HARTSEL
SOUTH
COLORADO SPRINGS

## Acknowledgments

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# A Summary of Research at The Manitou Experimental Forest in Colorado, 1937 – 1983

Howard L. Gary, Principal Hydrologist

Rocky Mountain Forest and Range Experiment Station[1]

**Abstract**

Results of selected studies for range, watershed, timber and wildlife management research are summarized to provide land managers, land-use planners, and land-use researchers with information to help evaluate consequences of land management practices in the Colorado Front Range ponderosa pine zone.

[1] *Headquarters is in Fort Collins, in cooperation with Colorado State University.*

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# A Summary of Research at The Manitou Experimental Forest in Colorado, 1937 – 1983

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## INTRODUCTION

The Manitou Experimental Forest was established in 1936 to study problems of land use as they relate to management of natural resources of the Colorado Front Range ponderosa pine zone. The Experimental Forest, administered by the Rocky Mountain Forest and Range Experiment Station, is 28 miles northwest of Colorado Springs in Manitou Park, Colorado. The Forest covers about 26 square miles in the South Platte River watershed. This large watershed supplies a major share of water consumed by Denver and other cities along the foothills of the Front Range. This watershed and similar adjacent drainages also contribute water used for irrigation in some of the most productive and intensively cultivated lands in the western United States. The Experimental Forest location in the "tension zone" between the Rocky Mountains and the Plains is characteristic of much of the land area along the Front Range in Colorado and is thus suited to study forest influences; mountain home and associated recreation development and wildlife; proper management of ponderosa pine,[2] Douglas-fir, and mountain bunchgrass types; revegetation of abandoned and submarginal farm land; erosion control; and stream improvement. This report presents selected summaries of completed and current research.

## PONDEROSA PINE LANDS

The ponderosa pine zone in the Front Range of the Rocky Mountains extends from southern Wyoming to northern New Mexico and encompasses approximately 4 million acres (fig. 1). These timbered lands include grassland parks, willow fields along streams, sagebrush and oak brush areas, and scattered cultivated fields. The land, vegetation, and climate of the Forest are typical of the eastern slope of the central Rocky Mountains.

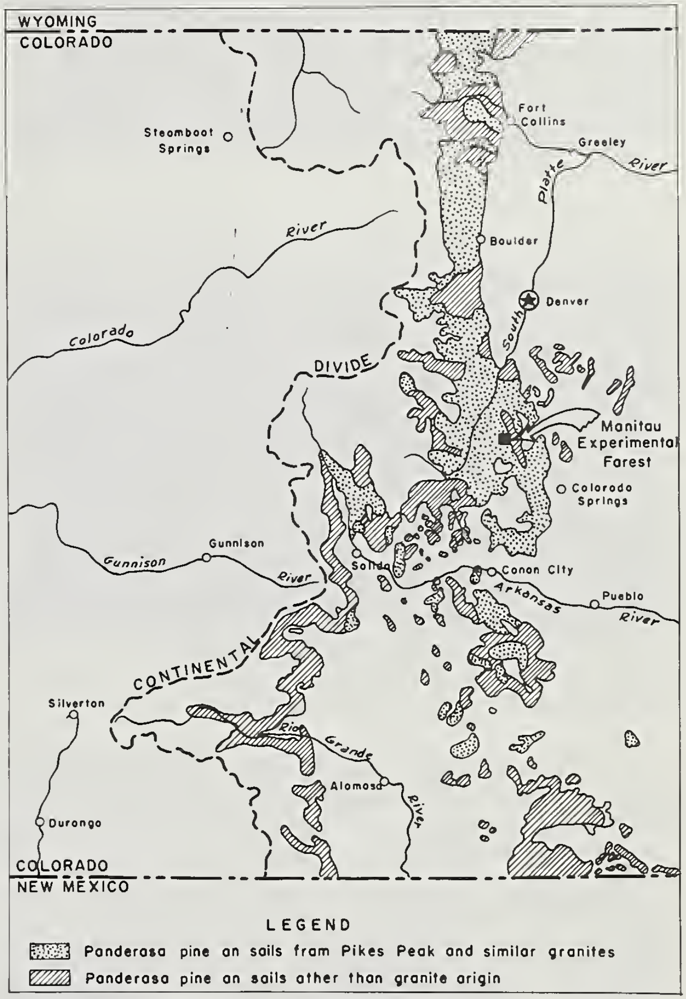


**Figure 1.—Distribution of ponderosa pine in Colorado (Love 1958).**

## LANDFORM AND GEOLOGY

The Experimental Forest is in a fault outlier about 30 miles long and 4 miles wide, flanked by the West Creek Range on the west and the Rampart Range on the east. The Forest is bisected by Trout Creek, a small perennial stream and tributary of the South Platte River. The eastern part (western exposure) of the Forest includes rugged mountains with narrow, steep-walled canyons. The western part includes mainly broad, gently rolling valleys and plateaus. Elevation ranges from about 7,500 to 9,300 feet.

Geologic erosion has exposed three sedimentary formations. The lowermost bed is the Sawatch quartzite, the next is Madison limestone, and the topmost is Fountain arkose. The Sawatch and Madison formations outcrop on the east side of the valley within a relatively narrow band. The Fountain arkose occurs chiefly on the east side of the valley; but, erosion pedestals up to 30 feet tall are scattered throughout the western part of the forest (fig. 2). Redeposition of alluvium at lower elevations has resulted in extensive crossbedding. The basement rock is coarse-textured Pikes Peak granite.

[2]*All plant names mentioned are listed in the appendix.*

## SOILS

Soils from biotite granite are by far the most extensive and occur in the rugged eastern half of the forest.[3] The surface soils are light brown, shallow, gravelly, low in organic matter, infertile, slightly acidic, and less than 10 inches thick. The bedrock is reddish brown, disintegrating granite. Surface soils on the western side of the forest are brown to dark brown sandy or gravelly loams, ranging from 8 to 18 inches thick. Subsoils, when present, are usually reddish brown, have sandy or gravelly clay loam texture, and may extend to depths of 20 inches or more. Most soils on the forest are susceptible to severe erosion whenever vegetative cover is removed.

## VEGETATION

Vegetation on the western part of the forest is mainly ponderosa pine in the overstory and bunchgrasses in the understory, with numerous scattered grassy openings or parks. Predominant bunchgrasses are mountain muhly and Arizona fescue. Abandoned fields have extensive stands of sleepygrass. Stringer meadows and willow thickets border Trout Creek. Similar vegetation grows on the eastern side of Trout Creek. Above about 8,000 feet elevation, the vegetation is dominated by stands of overmature ponderosa pine, Douglas-fir and aspen. Lodgepole pine grows at higher elevations along the eastern boundary of the forest. Some limber pine also is present. Engelmann spruce and blue spruce grow along the streambottoms and margins of wet meadows. Shrubs are scattered throughout the timber types.

## CLIMATE

The "dry subhumid," distinctly continental climate is characteristic of most eastern slope areas in Colorado. Winters are usually dry and often cold for long periods. The highest monthly precipitation falls during the cool summers. Annual precipitation at the forest headquarters (7,740 feet elevation) for the period 1937 through 1982 averaged 15.6 inches, and ranged from 7.6 inches in 1939 to 24.1 inches in 1969 (fig. 3). Seventy percent of the precipitation falls in the primary growing season, April through August. Snow may fall from late September to late May, and accounts for about 30% of the annual precipitation. High-intensity storms, which may produce runoff and erosion, occur most frequently during July and August. Storms producing surface runoff have been recorded each month from May through September.

[3]*Retzer, John L. 1940. Soils and physical conditions of the Manitou Experimental Forest, 35 p. Unpublished manuscript, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*

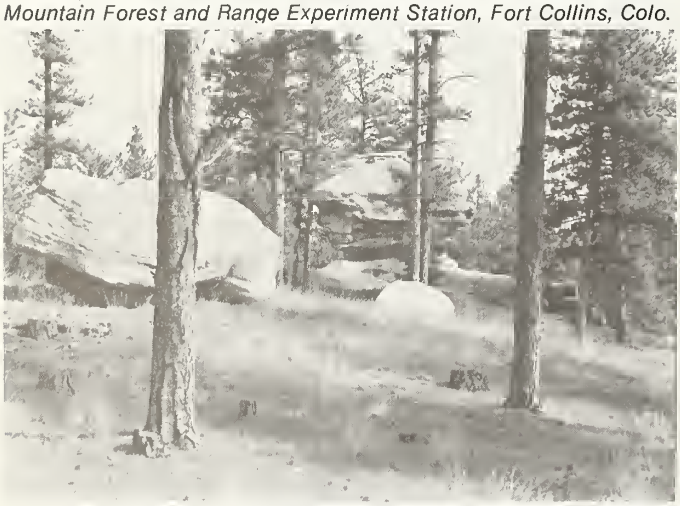

Figure 2.—Pedestals of Fountain arkose along the western side of the forest.

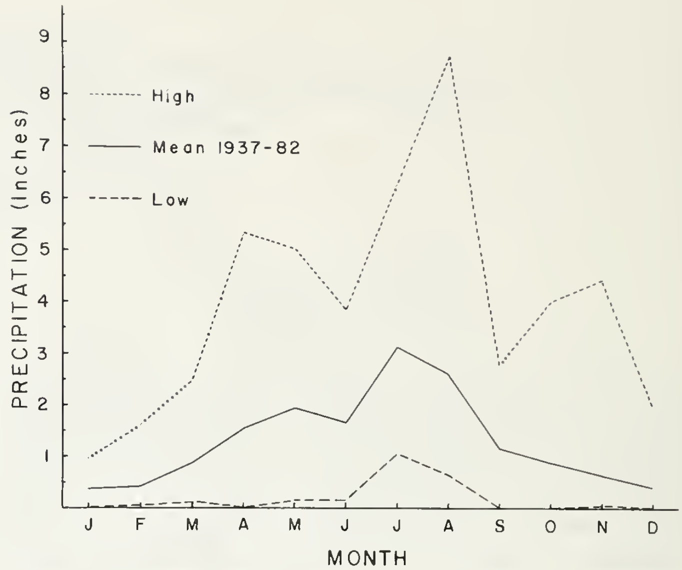


**Figure 3.—Means and extremes of monthly precipitation, 1937–1982.**

Yearly mean temperature for the period 1942–1958 averaged 40.6° F. Mean monthly temperatures varied from 23.0° F in January to 60.8° F in July (fig. 4). Temperatures during the summer seldom exceed 90° F and extreme winter temperatures have been −40° F. On the average, there are 113 days in the growing season, and the frost-free period extends from about May 28 to September 18.

## EARLY RESEARCH

Research first sought to develop better methods for management to perpetuate and restore the natural resources for long-term productivity. Range management and seeded pasture studies specifically sought to obtain maximum livestock production on native ponderosa pine-bunchgrass range and seeded pastures consistent with wise management of other resources. The watershed studies sought to determine how to revegetate depleted ponderosa pine watersheds to minimize flood and sedimentation damages from high intensity storms and to develop methods to improve water yields.

## NATURAL REVEGETATION OF ABANDONED FIELDS

Warm summers and rainfall during the growing season favor relatively rapid herbaceous plant succes-

sion on the Forest. Natural revegetation of some 600 acres of abandoned croplands began with an initial invasion of an annual forb type, progressed through perennial forbs, mixed grasses and forbs to a subclimax grass community (fig. 5). The annual forb stage lasts only a few years and is characterized by a few species occurring in great abundance. The perennial forb stage, lasting from 7 to 10 years, is characterized by an increased number of perennial grasses and forbs, such as western wheatgrass and thistles. The mixed grass and forb stage is initially characterized by an abundance of sleepygrass and slender wheatgrass and may last 10 to 25 years. In the subclimax bunchgrass stage, mountain muhly and Arizona fescue are the dominant species. Ponderosa pine probably is the potential climax vegetation for most of the abandoned fields.

A

B

Figure 5.—Natural plant succession on abandoned fields. A, *Stipa-Agropyron* community in a field abandoned 15 years; and B, Subclimax grass community on a field abandoned 62 years (Johnson 1945).

## GRAZING MANAGEMENT

Ponderosa pine-bunchgrass ranges have been an important vegetation type for range cattle in Colorado for more than 100 years. The optimum level of grazing in relation to range utilization, herbage production, weight gain, other plant responses and soil condition was not known in the early 1950s. The first studies were designed to determine proper grazing intensity. Later studies determined the best grazing intensity and livestock management on seeded pastures and animal-plant interactions.

### Native Pastures

Six experimental ponderosa pine-bunchgrass pastures, varying in size from 254 to 309 acres, were established in 1940. Two 2.5-acre enclosures were located within each pasture. Three grazing intensities—light, moderate and heavy cattle use—were applied to each of two pastures from 1941 to 1958. Utilization goals were based mainly on mountain muhly and Arizona fescue for the three grazing intensities—less than 20% removal of herbage produced for light, 30% to 40% for moderate, and over 50% for heavy grazing. The pastures were grazed five months each year, from June 1 through October 31, using yearling heifers (Hereford or Aberdeen Angus).

### Herbage Production

Production of palatable grasses and sedges over the six pastures averaged 250 pounds of air-dry forage per acre in 1938 and increased to 344 pounds per acre in 1942, the first year after beginning the grazing trials. About 43% of the herbage was mountain muhly. Near the end of the grazing study, in 1957, average herbage yields on light- and moderate-use pastures were slightly higher in 1957 than in 1942 and 1947 (fig. 6). On heavily grazed pastures, production dropped from 351 pounds per acre in 1942 to 195 pounds in 1947, and 148 pounds in 1957. Differential grazing also created marked differences in range condition (fig. 7).

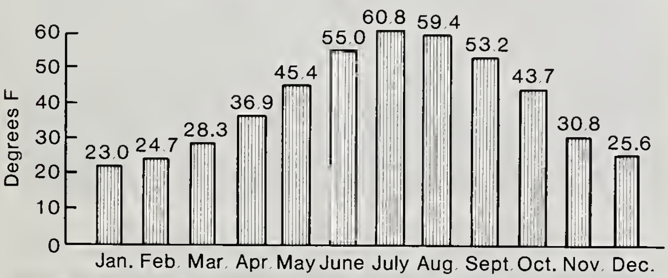


Figure 4.—Monthly mean temperatures, 1942-1958 (Berndt 1960).

### Use of Native Plants

Utilization of the six most commonly used species on the native pastures was estimated in 1950 and 1952, 6 and 8 years after starting the grazing intensity trials. Arizona fescue and mountain muhly furnished 94% of the forage on lightly and moderately grazed pastures. Little bluestem and sun sedge produced 5% of the forage. Blue grama was grazed sparingly under light and moderate grazing. Fringed sagebrush, not used under light grazing, received only 3% use under moderate grazing. Utilization of all six species on heavily grazed pastures was greater than on more lightly cropped pastures. Arizona fescue and mountain muhly

received the most use; however, these species furnished only 68% of the forage. Mountain muhly was the most productive species, while Arizona fescue was considerably reduced by prolonged close grazing.

### Grazing and Plant Responses

In the grassland vegetation type, perennial grass and sedge cover nearly doubled when grasslands were grazed lightly, increased by one-third under moderate use, and decreased nearly one-half under heavy grazing. Increases in perennial grasses and sedges indicated plant succession was largely responsible for changes in cover. Understory perennial grasses and forbs within both open and dense stands of timber showed a decreasing trend under all intensities of grazing, apparently in response to closure of the pine canopy.

### Weight Gains on Native Pastures

Seasonal cattle gains from 1943 through 1949, under about average annual precipitation, were 231, 221, and 176 pounds, under light, moderate and heavy use, respectively (fig. 8). The years 1950 through 1955 were characterized by drought, and cattle were removed from the pastures before October. Therefore, seasonal gains for this period were less. Cattle gained most during the first 2 or 3 months of the grazing season, when nutritional value of vegetation was highest. The proportion of gain made early in the season was directly related to grazing intensity.

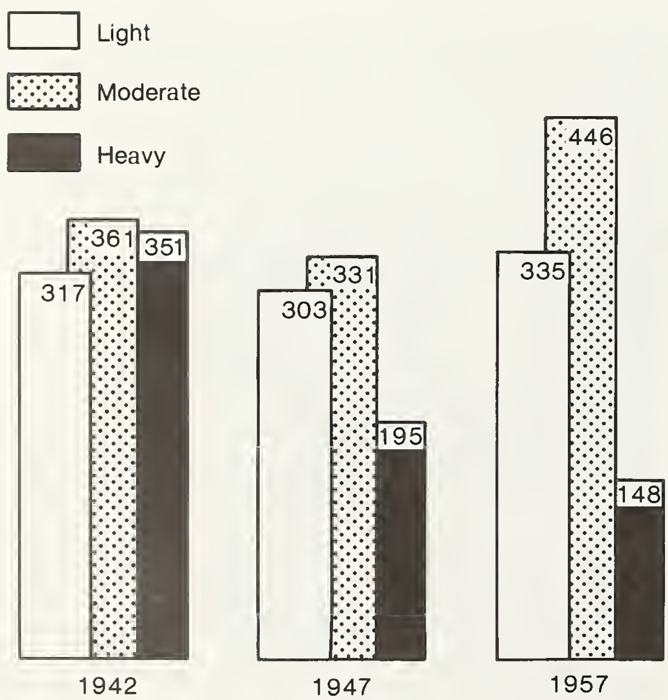


Figure 6.—Grass and sedge yield (pounds) as affected by grazing intensity (Smith 1967).

A

B

C

Figure 7.—Range condition on the native pastures. A, lightly grazed—one heifer per 25.5 acres; B, moderately grazed—one heifer per 14.5 acres; and C, heavily grazed—one heifer per 12.5 acres (adapted from Smith 1967).

### Seeded Pastures

In the Front Range pine type, natural recovery of abandoned farmlands and depleted pastures through plant succession can take decades even with no grazing. Seeding with introduced grasses and legumes in many cases can convert abandoned farmlands and depleted ranges to productive range within a few years. Much early research dealt with planting techniques, species adaptability and grazing intensity trials.

#### Species Adaptability

Seedings during the fall or early spring, when moisture was available for seed germination, showed about equal success for obtaining good stands of seeded grass on abandoned farmlands and/or depleted open grassland parks. Species most promising in adaptability to climate and soil conditions 3 to 8 years after seeding were crested wheatgrass, Sherman big bluegrass, smooth brome, intermediate wheatgrass, Russian wildrye, and yellow sweetclover.

#### Forage Yield of Seeded Species

Maximum forage production on abandoned fields seeded to crested wheatgrass, smooth brome, intermediate wheatgrass, Russian wildrye, and a mixture of crested wheatgrass, smooth brome and yellow sweetclover was generally greatest the third to fifth year after seeding (fig. 9). Precipitation during the growing season accounted for most of the difference in forage production and may have been the main limiting variable. Average forage production from 1948 through 1959 ranged from 1,358 pounds for the mixture to 663 pounds for smooth brome. Forage production of Sherman big bluegrass seeded in 1957 ranged from 2,394 pounds per acre under 16.3 inches of moisture in 1961, to 533 pounds under 15 inches of moisture in 1965.

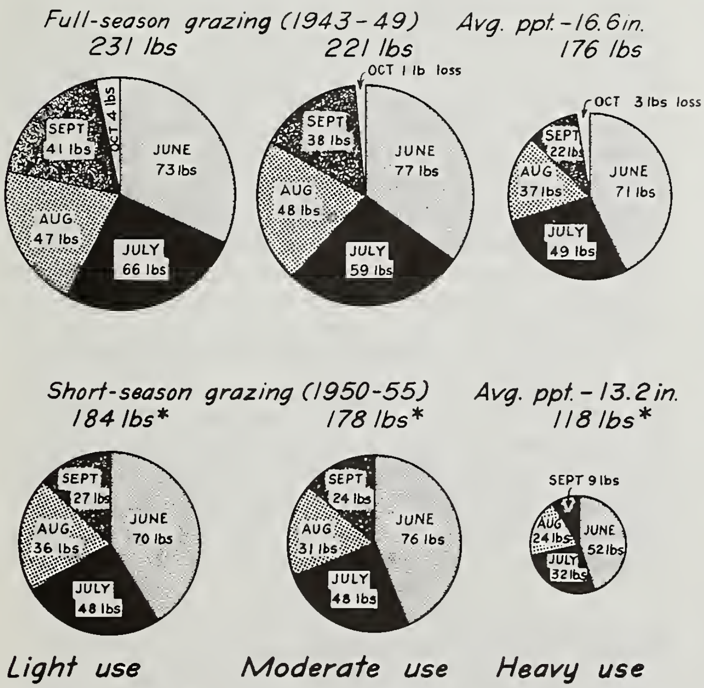


**Figure 8.**—Average monthly and seasonal gains under different grazing intensities (Smith 1967).

**Figure 9.**—A 4-year-old seeded stand of intermediate wheatgrass produced over 1,000 pounds of air-dry herbage per acre.

#### Grazing Intensity on Seeded Pastures

Intensity of grazing studies were conducted from 1948 through 1959 on 10-acre seeded pastures. The pastures included those seeded to crested wheatgrass, smooth brome, intermediate wheatgrass, Russian wildrye, and a mixture of crested wheatgrass, smooth brome and yellow sweetclover. Grazing use was based on average stubble heights of 1 and 2 inches, two levels of heavy use (65–85% utilization), and 4 and 6 inches, one level of intermediate (45% utilization) and light use (33% utilization), respectively.

More than twice as many heifer days of grazing per acre were obtained during a favorable growing season such as 1957 compared with a dry season such as 1954 (fig. 10). The most pronounced increase in use was on the more heavily grazed units. Crested wheatgrass, for example, was grazed from 45 to 48 days longer in 1957 than in 1954 on units grazed to 1- and 2-inch stubble heights. The mixture pasture was primarily crested wheatgrass in the final years of research. Animal days of grazing on smooth brome and intermediate wheatgrass were noticeably lower after heavy grazing in 1959 than in 1957; these species were not recommended for seeding in pure stands on depleted dry upland sites. Grazing to 3-inch stubble height was recommended for Russian wildrye, to avoid development of ungrazed wolf plants and eventual overgrazed local areas.

#### Weight Gains on Seeded Pastures

The mixture and crested wheatgrass pastures grazed to selected stubble heights provided the best sustained daily weight gain for yearling heifers (fig. 11). Smooth brome and intermediate wheatgrass stands provided

good daily gains and per acre gains early in the study; but overall, these species gradually deteriorated under all levels of use and were not suited to seeding in pure stands. Weight gains on Russian wildrye were relatively low compared to the mixture, crested wheatgrass and big bluegrass; but, this grass provided a source of forage during early spring. Beef production on Sherman big bluegrass pastures was superior to the other seeded species for gains per acre. Gains averaged about 75 pounds more than on a nearby moderately grazed native pasture. The high potential productive capacities of seeded pastures should be considered for incorporation into Front Range livestock management programs.

## Management and Grazed Plant Relations

Other studies determined cattle responses to supplemental feeding, nutritive quality of seeded and native pastures and grazing trials and forage yield.

### Supplemental Feeding on Seeded and Native Pastures

The responses of weaner calves were evaluated on seeded stands of Sherman big bluegrass, with and without protein supplement; and on native ponderosa

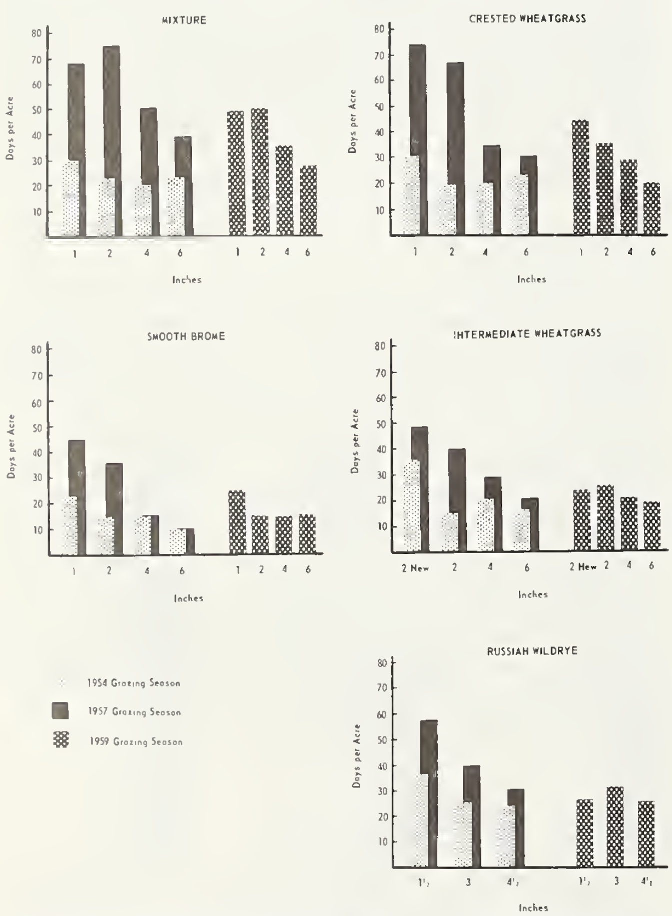


Figure 10.—Days of grazing on seeded pastures based on utilization stubble height at end of season (Currie and Smith 1970).

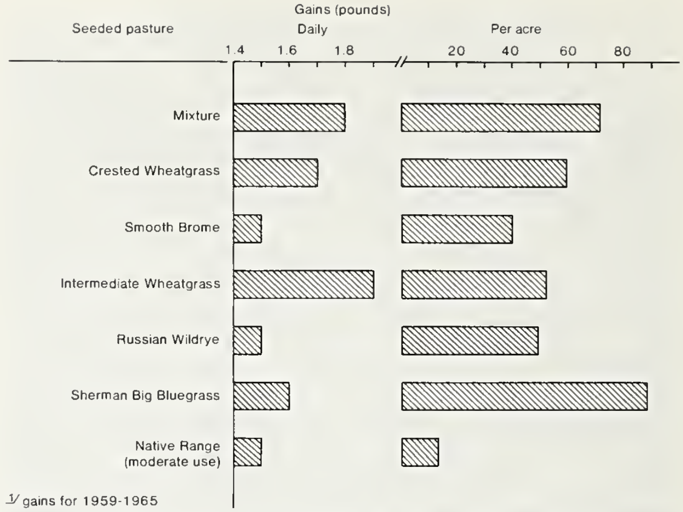


Figure 11.—Average weight gains of yearling heifers on seeded pastures, 1948-1959 (adapted in part from Currie and Smith, 1970).

pine-bunchgrass pastures plus protein supplement during late fall, winter and early spring grazing seasons from 1967 to 1971. Calves made small weight gains on all pastures during the fall, but usually lost weight during the winter and spring. On a per acre basis, gains from big bluegrass without supplement nearly equaled those of native grass plus 0.50 pounds of protein supplement per calf per day. With either 0.25 or 0.50 pounds of protein supplement per day, gains per acre on seeded big bluegrass pastures were double those obtained on native pasture.

### Nutritive Quality of Cattle Diets

The nutritive quality of forage available to two 12-cow herds on native pasture year-long and on native plus seeded pastures was determined from 1965 to 1966. One fistulated steer was incorporated into each herd. Crude protein in the diets of the two cow herds, assumed to be similar to steer diets, followed seasonal trends largely indicative of the effects of forage maturity (fig. 12). Levels were high in early spring, when forage plants were young and growing rapidly, then declined throughout the summer and autumn as the forage matured. The herd grazing the seeded pasture in the spring had an advantage of high protein levels approximately 30 days earlier than did the herd grazing native pastures. When the two herds were separated in late autumn, dietary protein levels of the herd grazing seeded Sherman big bluegrass rose sharply, whereas protein in the diet of the herd grazing native pasture continued to decline. Botanical composition of diets on the native pasture reflected heterogeneity of the pasture rather than preference for certain plant species.

### Grazing Trials on Crested Wheatgrass

Forage yield differences on pastures seeded to crested wheatgrass mainly resulted from amount of

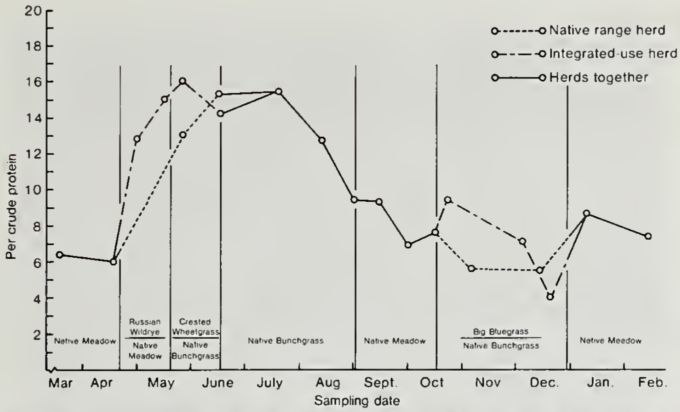


**Figure 12.—Annual trends of dietary crude protein in forage samples ingested by fistulated steers (Malechek 1966).**

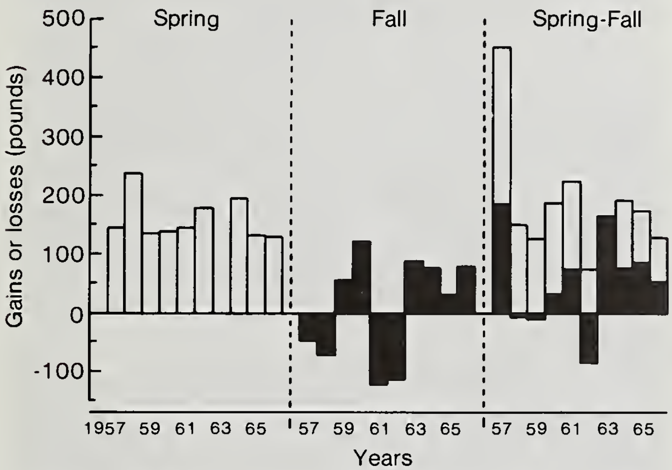


**Figure 13.—Heifer response on crested wheatgrass pastures grazed seasonally (Currie 1970).**

moisture received during the growing season, and not from seasonal grazing. Yields on spring-grazed pastures varied in response to April precipitation. Production on fall-grazed pastures varied in response to May–June moisture. Seasonal gains were not an intensity factor, but were related to season of grazing (fig. 13). The heifers consistently made good gains only during spring grazing.

## WATERSHED MANAGEMENT RESEARCH

Because of sporadic precipitation, early watershed management studies dealt primarily with ground cover, infiltration, surface runoff and erosion from soils developed from granitic and other geologic materials.

### Gully Control

Before establishment of the Experimental Forest, labor intensive erosion control measures were undertaken by the U.S. Civilian Conservation Corps. The effectiveness of their early gully control structures and deepening of gullies are of practical interest. Temporary control structures made of logs accomplished their intended objectives for many years, but eventually failed (fig. 14). Many of the check dams constructed of loose rock and mesh wire and keyed into gully banks and into the channel are still intact and have controlled gully erosion (fig. 15). Most gully systems in the forest can be traced to old wagon road ruts and cow trails in valley bottoms. Many such gullies are still active and will continue to slowly deepen and advance upslope indefinitely unless controlled (fig. 16).

1936

1981

**Figure 14.—Log check dams eventually fail and trapped sediments are washed downstream (1936, 1981).**

### Source of Stream Sediments

Upstream channel and gully erosion contributes to the sediment load carried by Trout Creek and to sedimentation of Manitou Lake. After completing the dam for Manitou Lake in 1937, the water storage capacity of the lake was about 93 acre-feet. In 1948, the capacity had been reduced by two-thirds, and approximately 60 acre-feet of sediment had been deposited in the lake. Total

sediments above and below the spillway level was about 200 acre-feet, with channel deposits as much as 1 mile upstream. The drainage area above the lake is about 69 square miles. An estimate of total sediment contribution from the drainage area is 18.2 acre-feet per year, or 0.26 acre-feet per square mile annually. An example of sedimentation and streambank cutting is illustrated in figure 17.

### Bunchgrass Runoff Plots

Watershed management studies started in 1937 utilized runoff plots (fig. 18). The main purpose was to determine the influence of gravelly alluvium (outwash of Pikes Peak granite) and grazing use on surface runoff and erosion. In the period 1937 through 1952, yearly precipitation ranged from 7.6 to 24.0 inches, and averaged 15.6 inches. Annual forage production averaged about 900 pounds per acre. After a 4-year period of nonuse, runoff and erosion amounts were assessed. A heavy and moderate cattle grazing treatment was then applied. For 12 summers of grazing average runoff ranged from 0.34 inches on the heavily grazed plots to 0.11 inches on the ungrazed plots (fig. 19). Average annual soil losses varied from 134 pounds on ungrazed plots to 316 pounds per acre on heavily grazed plots. The model cloudburst storm causing erosion on the runoff plots was 0.96 inches of precipitation. Such storms occur once or twice during the summer, and produce effects shown in figure 20.

### Ponderosa Pine Watersheds

Six contiguous watersheds, ranging from 1 to 2 acres in size, on granitic alluvium and draining to the west were instrumented in 1938 to determine the influence of ponderosa pine (75–100 years old) and its removal on surface runoff and sediment yields. The net result was conversion to grass cover with scattered colonies of aspen, and brush (fig. 21). Average surface runoff dur-

Figure 15.—A rock and wire check dam installed in 1936 was effective in 1983.

A

B

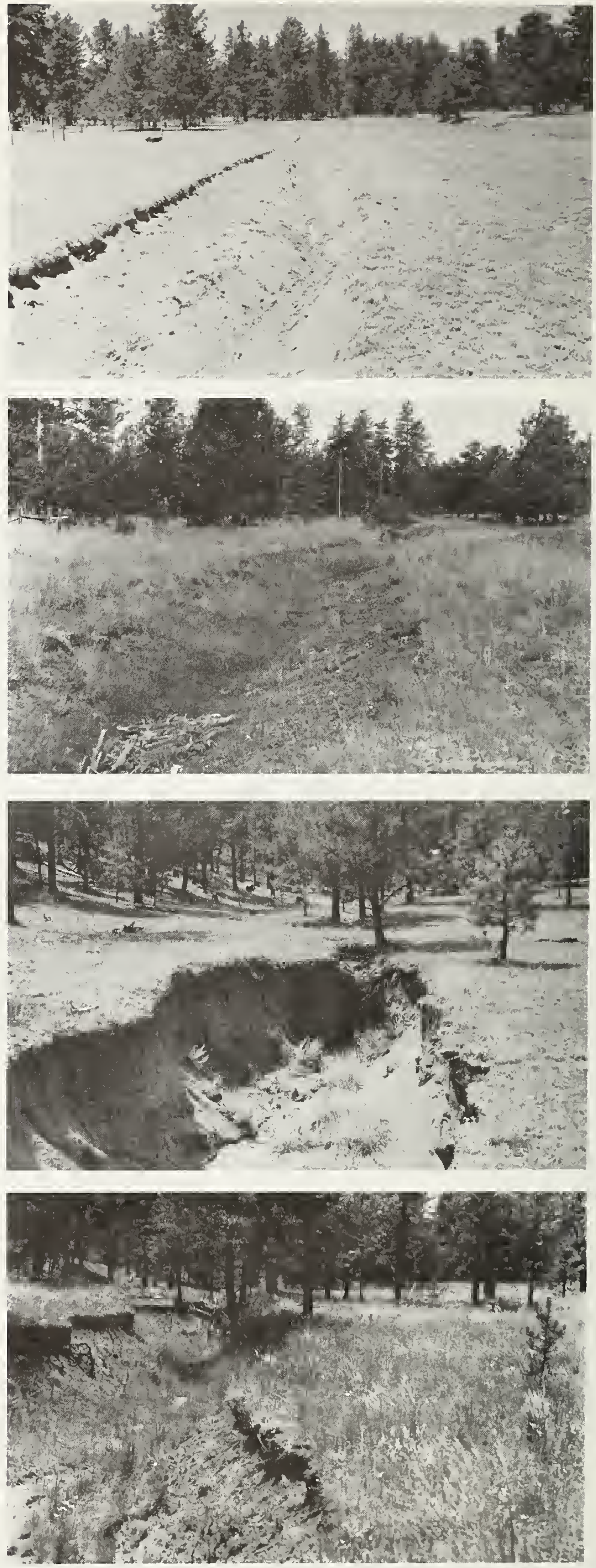

Figure 16.—Erosion problems on the Forest. A, an abandoned road; and B, active headcutting in an old cow trail. This gully has advanced 55 feet upslope in 33 years.

Figure 17.—Sedimentation over the Trout Creek floodplain. The stream channel has shifted many times during floods. In 1980, remains of cross-ties for a railroad abandoned in 1887 were 3 feet below the soil surface.

Figure 18.—Native bunchgrass surface runoff plots. The horizontal area of each plot is 0.01 acre.

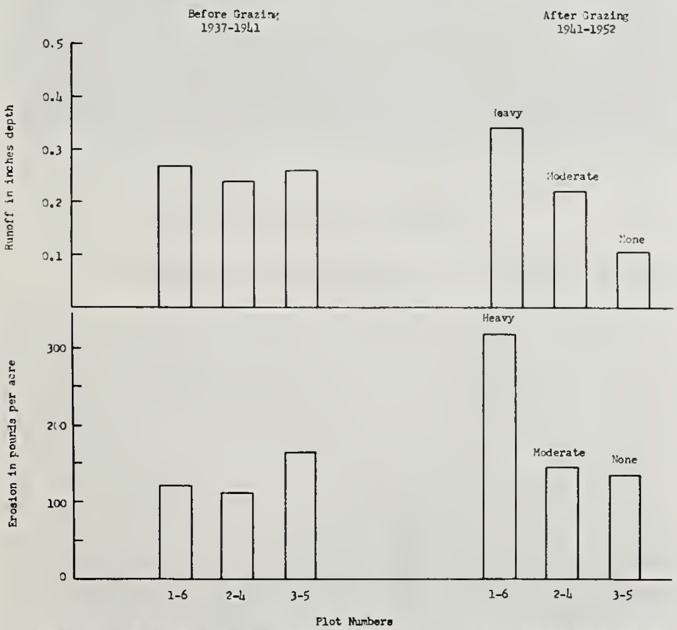


Figure 19.—Average runoff and erosion from summer storms on bunchgrass runoff plots (Dunford 1954).

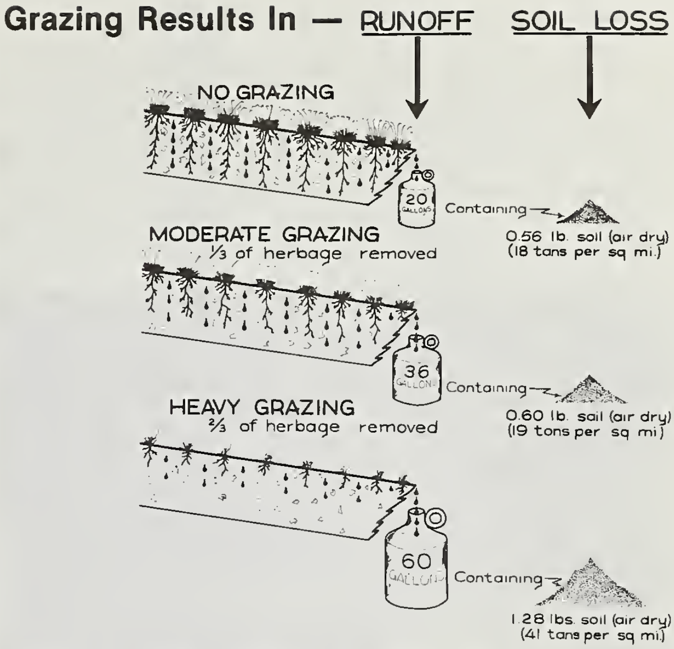


Figure 20.—Average soil loss and surface runoff from the model summer storm of 0.96 inches (Love and Johnson, 1952).

ing the first 6 years after type conversion increased from 2 to 5 times pretreatment runoff. Thereafter, the rapid increase and spread of native bunchgrasses provided almost complete protection against surface runoff and erosion. The erosion caused by rainstorms was erratic before and after type conversion and was of little practical significance. Only a small amount of sediment has been caught in runoff tanks at the mouth of the drainages in the past 30 years.

### Infiltration on Native Pastures

Infiltration of precipitation was determined by rainfall-simulators (2.5 ft² of surface area) on six native range pastures from 1941 through 1954. The main purposes were to evaluate the relation of plant cover to infiltration and how these were affected by soil properties and cattle grazing.

### Infiltration, Plant Cover and Soil Properties

Litter was the only vegetation factor consistently associated with infiltration. The value of litter in increasing infiltration and reducing surface runoff is well established. Based on 108 infiltration runs in all cover types, during 1941, 1946 and 1952, the quantity of dead organic material was significantly correlated with higher infiltration rates. Infiltration averaged 2.50, 1.78 and 1.15 inches per hour under pine-litter, pine-grass and grassland, respectively. Sand content, soil fraction passing a 2-mm screen, was the best indicator of the influence of texture on infiltration. Noncapillary pore volume was the most important soil factor related to infiltration during all years of study.

### Infiltration After Protection from Grazing

Infiltration rates determined in 1941, at 24 random locations stratified by cover types, in the native pasture exclosures, and at 108 sites in the six native range pastures, were not statistically different. Differences inside and outside the exclosures in subsequent years were assumed to be the result of protection from grazing (fig. 22). Regardless of grazing intensity, infiltration rate did not materially improve under any intensity of grazing. Only complete protection from cattle grazing appeared to improve infiltration rate.

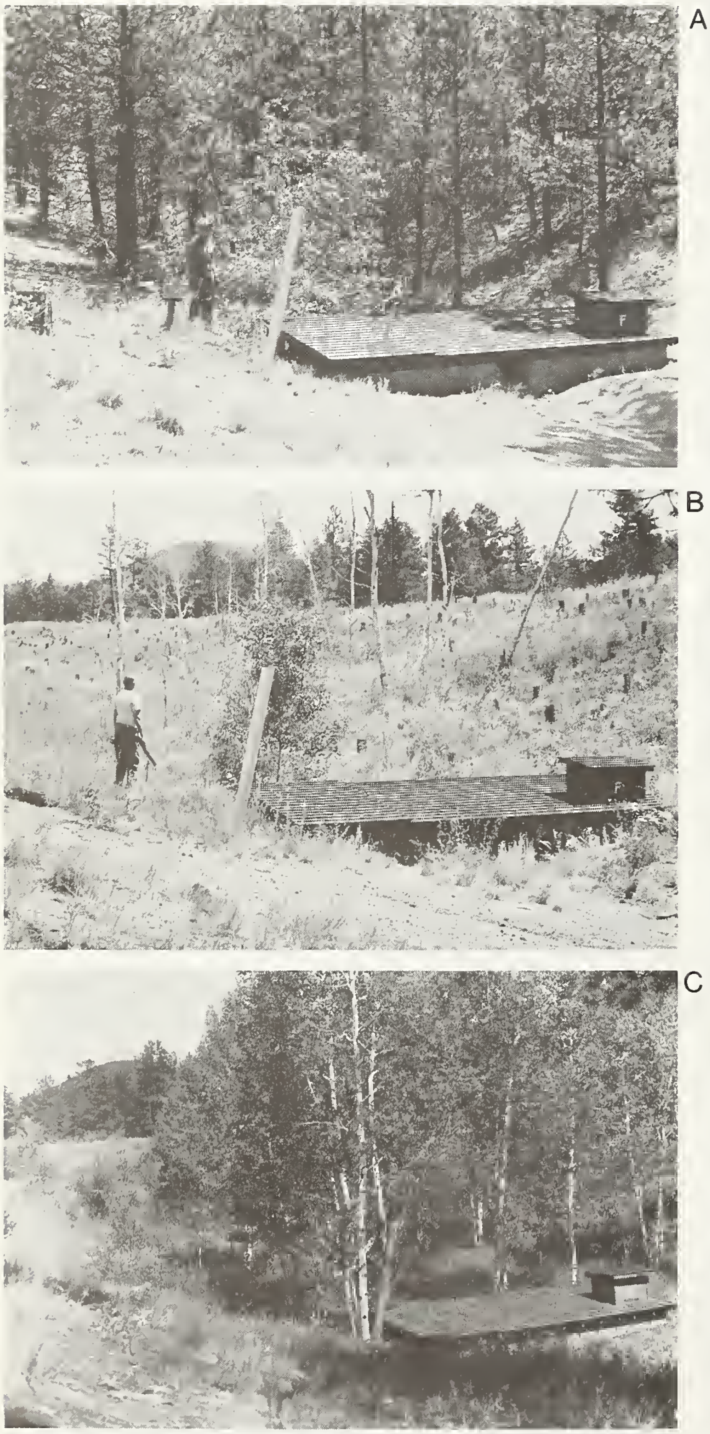

Figure 21.—Ponderosa pine watershed F. A, north aspect before treatment in 1948; B, two years after logging and slash burning, 1950; and C, in 1983.

### Runoff from Missouri Gulch Watershed

Measurements of precipitation and streamflow were obtained from the Missouri Gulch watershed from 1940 through 1958, to gain information on water yield and its relation to precipitation. No other perennial streams have been gaged in the Experimental Forest (fig. 23).

### Watershed Description

The watershed covers about 4,600 acres in the northeastern part of the forest, and has 6.1 miles of live channel. Elevation ranges from about 7,300 to 9,300 feet. Slopes range from 10% to 60%, and residual soils are mainly gravelly sandy loams and stony loams. Plant cover is mainly ponderosa pine and Douglas-fir, with lodgepole pine at the higher elevations, and Engelmann spruce and aspen along the streams. Scattered brush, grass, erosion pavement, and bare rock also are present.

### Precipitation and Streamflow

Annual precipitation on the watershed ranged from 12.2 inches in 1950 to 27.1 inches in 1957, with a mean of 18.2 inches for 19 years of record. Seasonal precipitation was greatest during April through August (fig. 24). Streamflow was lowest during the winter and early spring, rose sharply to late spring peaks, and decreased gradually thereafter. Maximum peak flows resulting from snowmelt occurred as early as April 21 and as late as May 14. Generally, more than 60% of the seasonal runoff left the watershed in April and May, but it varied greatly from year to year (fig. 25). Proportion of water year precipitation becoming streamflow ranged from 3.4% to 13.3%, with an average of 7.9% for the period 1952 through 1958.

## CURRENT RESEARCH

## REGENERATION OF PONDEROSA PINE

A long-term study was started in 1980 to compare and quantify shelterwood and seed-tree cutting methods for regeneration of new even-aged patches and stands of ponderosa pine (fig. 26).[4] The information is expected to help provide management guidelines to regenerate overmature even-aged patches and stands. Scarified and unscarified site preparation treatments were used to study natural and artificial regeneration. Survival of natural seedlings after two growing seasons is presented in figure 27. Survival of planted 2–0 stock, after two grow-

[4]*Personal communication with S. E. McElderry, Research Forester, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*

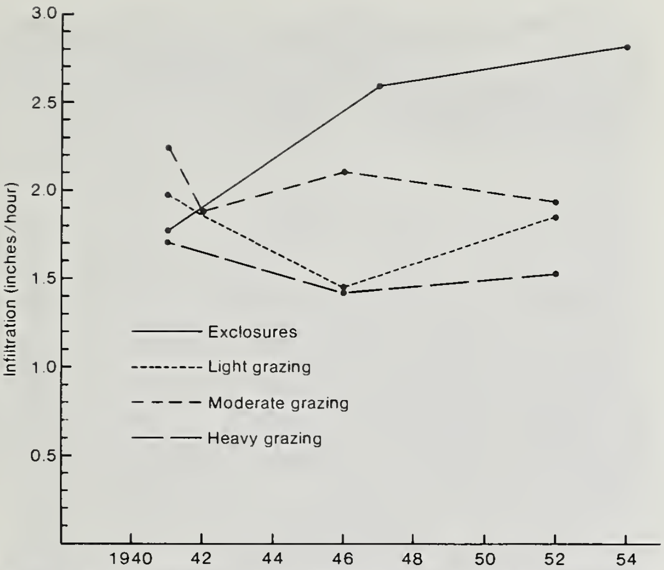


**Figure 22.—Comparison of infiltration trends in exclosures with those under grazed pastures (adapted from Dortignac and Love 1961).**

**Figure 23.—Combination San Dimas flume and broadcrested weir gaging station near the mouth of Missouri Gulch.**

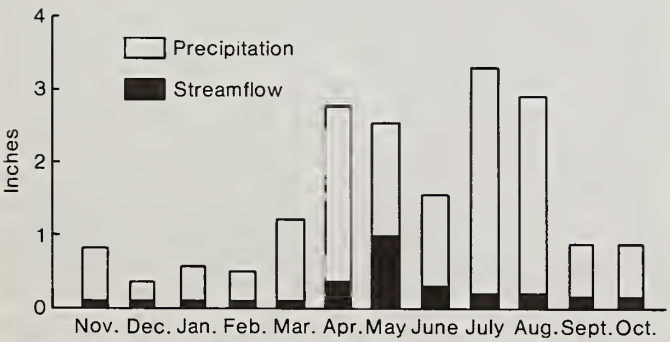


**Figure 24.—Monthly mean precipitation and streamflow for Missouri Gulch watershed, 1940-1958 (Berndt 1960).**

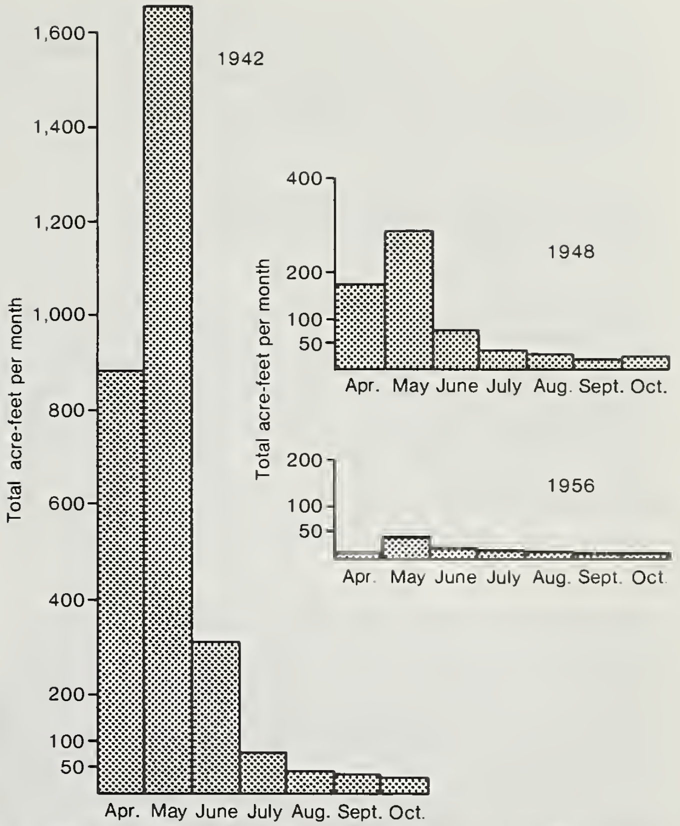


**Figure 25.—Seasonal streamflow extremes for the Missouri Gulch watershed (Love 1958).**

**Figure 26.—Shelterwood and seed-tree plots in ponderosa pine (shelterwood, seed tree).**

ing seasons, was greater on scarified plots than on unscarified plots. Seedfall and germination, determined from seed trap contents, varied greatly the first 2 years. Seedfall was two times greater the first year, and germination percentage was 38 times greater.

## INITIAL TREE SPACING AND GROWTH OF PONDEROSA PINE

A long-term study was begun in 1983 to determine the effects of initial tree spacing on growth of young ponderosa pine (fig. 28).[5] Height and diameter growth as well as crown width and length will be measured for at least 30 years. Results of this study are expected to provide guidelines for optimum planting densities for artificial regeneration and for management of young, even-aged, naturally regenerated stands of ponderosa pine.

## PROVENANCE TESTING OF PONDEROSA PINE

A 20-year plantation study was started in 1981 in cooperation with Colorado State University. The main objectives are to determine the relative performance and evaluate patterns of survival, growth, phenology and morphology of ponderosa pine trees derived from 75 seed collection zones delineated for Colorado. Another

Figure 28.—Shaded ponderosa pine seedlings, initial spacing and growth study.

objective is to determine the degree to which seed can be used in other seed collection zones. Measurements during and after the growing season include height, diameter, growth cessation, and growth resumption. Other measurements include insect, disease, animal and weather damage.

*[5]Personal communication with C. B. Edminster, Mensurationist, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*

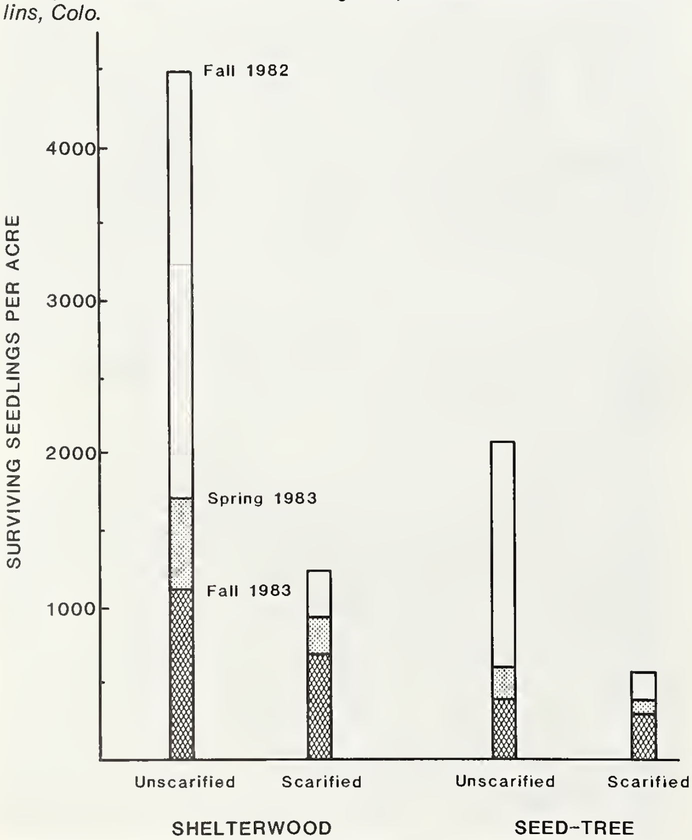


Figure 27.—Early survival of seedlings originating from 1981 seedfall.

## GROWTH AND YIELD OF MANAGED PLANTATIONS

Another long-term study was started in 1981 to compare growth responses of even-aged, pole-sized ponderosa pine over a wide range of growing stock levels (GSL's).[5] Diameters, basal areas, heights, volumes, numbers of live trees, growing stock levels, and dwarf mistletoe ratings will be remeasured at 5-year intervals and will be compared with changes predicted by existing growth and yield models (fig. 29). These data will provide a basis for formulating silvicultural prescriptions, management guidelines, and verification of existing growth and yield models for even-aged stands of ponderosa pine.

## GROWTH AND YIELD IN UNEVEN-AGED PONDEROSA PINE

In many areas where scenic and recreation use predominate, a major management goal is to maintain uneven-aged stands of ponderosa pine.[5] The uneven-aged stands are characterized by trees of many sizes, intermingled singly or in groups. Growth predictions for these uneven-aged stands are needed to control management activities and to evaluate interactions among resources. The objective for one ongoing study is to develop a generalized technique suitable for use in simulations. The new techniques will be applicable to stands managed as uneven-aged stands, and uneven-aged stands that will eventually be converted to even-aged structure. The measurement of individual tree variables has been completed, and growth prediction functions are being developed.

## DWARF MISTLETOE CONTROL IN PONDEROSA PINE

Dwarf mistletoe-infected ponderosa pine trees are removed in all timber sales on the Experimental Forest.[5] Since 1974, more than 60,000 ponderosa pine and 10,500 Douglas-fir seedlings have been planted in areas clearcut to control mistletoe. Studies are underway in past timber sale areas to determine optimum tree thinning levels to slow the spread of dwarf mistletoes, and to minimize damage from other tree diseases. A computer program, RMYLD, for ponderosa pine, provides a tool to aid foresters in managing mistletoe-infected and healthy forests.

Figure 29.—Ponderosa pine in a 1936 plantation on site index 50 land and thinned in 1981. Photographs taken 1983 (GSL-40, GSL-80, GSL-120).

## PONDEROSA PINE AND UNDERSTORY PLANT GROWTH

Studies are underway to determine the long-term influence of thinning pine canopies to various basal areas on growth and production of understory vegetation.[5] Fourteen permanent plots were established in the open-timber, native range pastures on the basis of basal area of ponderosa pine and understory vegetation. Basal areas range from about 25 to 90 square feet per acre. Production of understory vegetation is estimated with a heterodyne vegetation meter and by weighing forage clipped from subplots. Production estimates and phenology are also determined from time to time for each of the major forage plants—mountain muhly, Arizona fescue, blue grama, fringed sagebrush, and sun sedge.

## HABITAT USE AND REQUIREMENTS OF FLAMMULATED OWLS

Little is known about the flammulated owl's (fig. 30) habitat requirements, other than they seem to be associated with mature conifer forests, and are perhaps eliminated in logged areas where cavity trees and other elements are removed. A study has been conducted to determine breeding densities and habitat affinities in an old-growth ponderosa pine—Douglas-fir forest.[6] The owls migrate to the Experimental Forest about the first week in May, and select nest sites in cavities in old mature trees and snags. They migrate again in mid-October. They are insectivorous, and their diets include moths, beetles, grasshoppers, crickets, large flies and spiders.

Two years of telemetry study on seven nesting pairs indicated home ranges varied in size from 8 to 25 ha. Principal determinant of home range size appears to be patchiness of habitats or the intermixing of young dense stands of Douglas-fir, aspen, blue spruce along with mature ponderosa pine—Douglas-fir stands. The highest density of nesting pairs occurs in continuous stands of mature ponderosa pine—Douglas-fir. The owls tend to intensively forage in one to four open patches, about 0.1 to 1.4 ha each, within old-growth stands in their home range. The distance from forage areas to nests has ranged from 20 to 400 m. These and other data will provide a base with which to compare the ecology and population density of the owls in managed forests.

## CATTLE GRAZING AND WATER QUALITY

The effect of seasonal cattle grazing on water quality is under study in pastures bisected by Trout Creek. Selected water quality parameters are measured in the stream above and below the cattle. The distribution and frequency of waste discharges and weight estimates of manure deposited near the stream have provided general evidence as to how streams may be enriched and/or

[6] *Personal communication with R. T. Reynolds, Wildlife Biologist, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*

polluted by cattle. Results to date have shown minor local decreases in water quality, mainly bacteriological properties, when cattle are present. Based on moderate rates of grazing and generally adequate streamflow for manure and urine dilution, permanent removal of cattle does not appear to be necessary for good water quality maintenance.

## POLLUTION INDICATOR BACTERIA IN LAKE AND STREAM WATER

Studies are underway to quantify the impact of lake-based recreation and mountain home development on surface water quality. Densities of indicator bacteria, such as total coliforms, fecal coliforms, and fecal streptococci in water, provide one measure of water quality. These bacteria are eliminated in large numbers in fecal waste, and their presence usually indicates that intestinal waste products have reached a water source.

### Manitou Lake

The effect of lake-based recreation on water quality has been examined at Manitou Lake, a 12-acre reservoir, at the south end of the Experimental Forest. Daily visitor use starting in May ranges from none during stormy weather to several hundred during peak use. Recreational use at the lake (fig. 31) has not degraded water quality, based on densities of indicator bacteria. From July 1 to July 7, 1976, which included a period of major recreational use, fecal coliform densities in water entering Manitou Lake averaged 99 colonies per 100 ml of water. Fecal coliform densities leaving the lake averaged 2 colonies per 100 ml of water. Water quality actually improved from the lake inlet to the outlet, perhaps because of detention time and/or ultraviolet radiation.

### Domestic Water Supply

Indicator bacteria in the domestic water supply at the forest headquarters have occasionally exceeded the state primary standard (less than 1 fecal coliform per

Figure 30.—Flammulated owl parent and fledglings. Adult height is about 6 inches, and wingspan 14 inches (photograph courtesy of Art Wolfe).

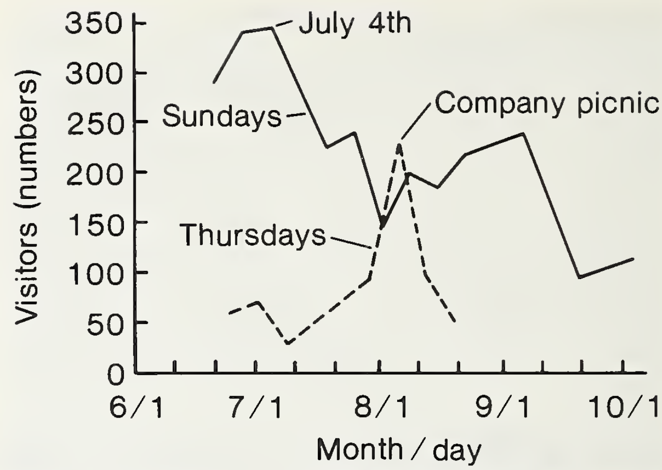


Figure 31.—Visitors at noon for selected Thursdays and Sundays at Manitou Lake, summer 1976 (Ponce and Gary 1979).

100 ml of water) for safe drinking water. Groundwater and streamflow from nearby Hotel Gulch is intercepted by a perforated steel pipe about 6 feet below the streambottom. The water collects in an underground concrete storage tank, and is conveyed to the headquarters through a pipeline. In mid-August counts of fecal streptococci indicator bacteria in the water supply, apparently from wildlife and insects, often averaged 150 colonies per 100 ml of water. The presence of these bacteria in the domestic water supply indicates incomplete filtering of biological pollutants through the coarse textured granitic alluvium near the water intake pipe. Incomplete filtering of biological pollutants near shallow domestic wells and springs likely occurs over a wide area of the Front Range.

## AQUATIC BIOTA IN TROUT CREEK

Surveys of aquatic biota, mainly macroinvertebrates, algae, and fish, have been conducted periodically since 1976 in Trout Creek.

### Macroinvertebrates

Aquatic macroinvertebrates (underwater stages of aquatic insects) are sensitive to subtle chemical and physical changes in stream water. Because of low motility, they provide a natural monitor and quantitative means of assessing effects of erosion from road and home construction, sewage and other waste discharges, streamside shade removal, and other land uses. Most families and species of aquatic insects in the Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) orders are indicators of clean water conditions. Their composition in macroinvertebrate communities varies according to site (fig. 32). The absence of stoneflies below the Manitou Lake dam probably is related to the influence of the lake, because they increase with distance both above and downstream from the lake. The Diptera (true flies) order contains many families and species which tolerate a wide range

of environmental conditions. A total of 78 taxa of aquatic macroinvertebrates have been collected and identified in Trout Creek.

### Algae

Pollution discharges into streams may enrich water and stimulate the surface growth or "blooms" of algae and affect water use. Composition of algae in Trout Creek varies according to site and season. A total of 57 genera from Bacillariophyta, Chlorophyta, Chrysophyta, Cyanophyta, Euglenophyta and Rhodophyta divisions have been collected. Chlorophyta (green algae) is the most abundant division collected at a site 2.5 miles above Manitou Lake. The genus *Cladophora*, typical filamentous green alga, is dominant, and its presence usually indicates high nutrient concentration in streams. Rhodophyta (red algae) is the most prevalent division at the lake inlet in late summer. Bacillariophyta (diatoms) is the most abundant division collected below the lake; but, green algae is more prevalent in the fall—possibly because of cooler temperatures and reduction of diatom populations. The Chlorophyta division, mainly *Cladophora*, is also most common 1.9 miles below Manitou Lake.

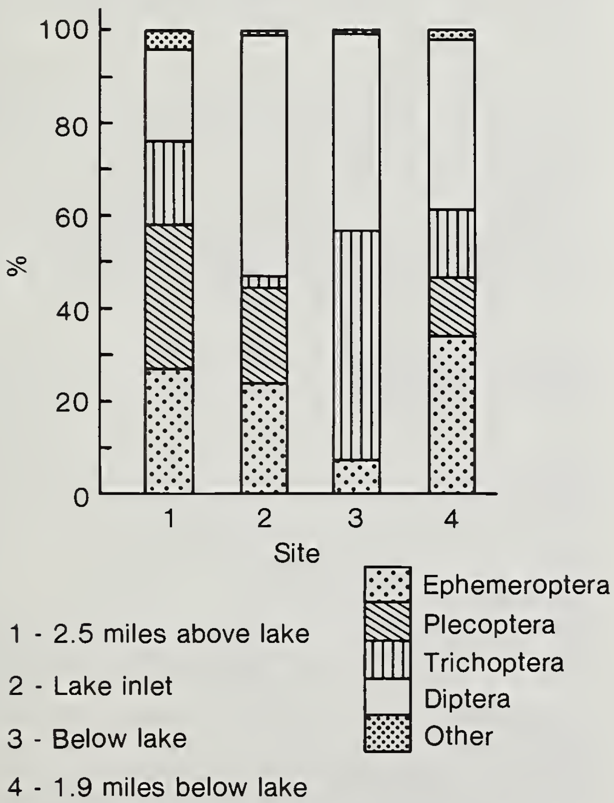


**Figure 32.—Percentage composition of macroinvertebrates by density for Trout Creek above and below Manitou Park Lake (adapted from Short et al. 1978).**

### Fish

The abundance and composition of fish fauna in Trout Creek has been determined by DC electro-shocking and seining at selected study sites. Brook trout (*Salvelinus fontinalis*) is the dominant species 2.5 miles above Manitou Lake; but, its relative abundance is greatly reduced near the lake inlet and below the dam. Relative populations also increase 1.9 miles below the dam. Speckled dace (*Rhinichthys osculus*) and sand shiner (*Notropis stramineus*) are most common near the inlet of Manitou Lake. The greatest diversity of fish is found below Manitou Lake dam and where many western longnose suckers (*Catostomus catostomus* and white suckers (*C. commersoni*) are found.

## WATER QUALITY IN THE NATURAL ENVIRONMENT

Water quality in "near pristine" streams, such as upper Hotel Gulch and Missouri Gulch on the Forest, may provide benchmarks with which to gage human impact on more highly developed land areas, such as the upstream areas along Trout Creek. Seasonal samples of stream water from the pristine streams (elevation about 8,700 feet) and from the main stream of Trout Creek (elevation about 7,700 feet), below diversely developed areas, indicate higher chemical pollution levels in Trout Creek. Low seasonal dissolved solids are associated with spring rains and/or snowmelt runoff, and high total dissolved solids with low baseflows in the fall. Fecal coliform densities in grazed sections along Trout Creek average about 14 times greater than fecal coliform densities found in the streams originating in the Hotel Gulch and Missouri Gulch natural areas.

## ADMINISTRATION

The facilities of the Manitou Experimental Forest are used from time to time for training schools, graduate field work, and field meetings of forestry and conservation societies. Research at the Experimental Forest is coordinated with research elsewhere to provide knowledge about many interrelated uses of forest lands. Because research deals with the effect of use on renewable resources, it requires a long time to accomplish. Opportunities are extensive for graduate students to undertake fundamental research in the conservation and use of natural resources. Arrangements may be made through colleges, universities, foundations, or other interested groups and the USDA Forest Service on a cooperative basis. Visitors are always welcome. To obtain more detailed published information about the experimental work send requests to Director, Rocky Mountain Forest and Range Experiment Station, 240 West Prospect Street, Fort Collins, Colorado 80526.

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# APPENDIX

## Species List of Principal Plants[1]

### Grasses and Grasslike

| Common Name | Scientific Name |
|---|---|
| Crested wheatgrass | *Agropyron cristatum* (L.) Gaertin. |
| Intermediate wheatgrass | *Agropyron intermedium* (Host) Beauv. |
| Quack grass | *Agropyron repens* (L.) Beauv. |
| Western wheatgrass | *Agropyron smithii* Rydb. |
| Bearded wheatgrass | *Agropyron subsecundum* (Link) Hitchc. |
| Slender wheatgrass | *Agropyron trachycaulum* (Link) Malte |
| Redtop | *Agrostis alba* L. |
| Little bluestem | *Andropogon scoparius* Michx. |
| Pine dropseed | *Blepharoneuron tricholepis* (Torr.) Nash |
| Sideoats grama | *Bouteloua curtipendula* (Michx.) Beauv. |
| Blue gramas | *Bouteloua gracilis* (H. B. K.) Steud. |
| Nodding brome | *Bromus anomalus* Fourn. |
| Fringed brome | *Bromus ciliatus* L. |
| Weeping brome | *Bromus frondosus* (Shear) Woot. & Standl. |
| Smooth brome | *Bromus inermis* Leyss. |
| Water sedge | *Carex aquatilis* Wahl. |
| | *Carex brevipes* W. Boott |
| | *Carex disperma* Dewey |
| Needleleaf sedge | *Carex eleocharis* Bailey |
| Silvertop sedge | *Carex foena* Willd. |
| Sun sedge | *Carex heliophila* Mack. |
| Smallwing sedge | *Carex microptera* Mack. |
| Nebraska sedge | *Carex nebraskensis* Dewey |
| Silver sedge | *Carex praegracilis* W. Boott |
| Ross sedge | *Carex rossii* Boott |
| Beaked sedge | *Carex rostrata* Stokes |
| Bluejoint reedgrass | *Calamagrostis canadensis* (Michx.) Beauv. |
| Northern reedgrass | *Calamagrostis inexpansa* Gray |
| Purple pinegrass | *Calamagrostis purpurascens* R. Br. |
| Orchardgrass | *Dactylis glomerata* L. |
| Timber danthonia | *Danthonia intermedia* Vasey |
| Parry danthonia | *Danthonia parryi* Scribn. |
| Common spikesedge | *Eleocharis macrostachya* Britt. |
| Russian wildrye | *Elymus junceus* Fisch. |
| Arizona fescue | *Festuca arizonica* Vasey |
| Sheep fescue | *Festuca ovina* L. |
| Thurber fescue | *Festuca thurberi* Vasey |
| Tall mannagrass | *Glyceria elata* (Nash) M. E. Jones |
| Foxtail barley | *Hordeum jubatum* L. |
| Baltic rush | *Juncus balticus* Willd. |
| Regels rush | *Juncus saximontanus* Nels. |
| Poverty rush | *Juncus tenuis* Willd. |
| Prairie junegrass | *Koeleria cristata* (L.) Pers. |
| Perennial ryegrass | *Lolium perenne* L. |
| Mountain muhly | *Muhlenbergia montana* (Nutt.) Hitchc. |
| False buffalograss | *Munroa squanosa* (Nutt.) Torr. |
| Roughleaf ricegrass | *Oryzopsis asperifolia* Michx. |
| Indian ricegrass | *Oryzopsis hymenoides* (R. & S.) Ricker |
| | *Oryzopsis pungens* (Torr.) Hitchc. |
| Timothy | *Phleum pratense* L. |
| Sherman big bluegrass | *Poa ampla* Merr. |
| Bulbous bluegrass | *Poa bulbosa* L. |
| Canby bluegrass | *Poa canbyi* (Scribn.) Piper |
| Mutton bluegrass | *Poa fendleriana* (Steud.) Vasey |

| | |
|---|---|
| Inland bluegrass | *Poa interior* Rydb. |
| Fowl bluegrass | *Poa palustris* L. |
| Kentucky bluegrass | *Poa pratensis* L. |
| Tumblegrass | *Schedonnardus paniculatis* (Nutt.) Trel. |
| Falsemelic | *Schizacne purpurascens* (Torr.) Swallen |
| Panicled bulrush | *Scripus microcarpus* Presl. |
| Bristlegrass | *Setaria viridis* (L.) Beauv. |
| Bottlebrush squirreltail | *Sitanion hystrix* (Nutt.) J. & Sm. |
| Subalpine needlegrass | *Stipa columbiana* Macoun. |
| Needle-and-thread | *Stipa comata* Trin. & Rupr. |
| Sleepygrass | *Stipa robusta* (Vasey) Scribn. |
| Scribner needlegrass | *Stipa scribneri* Vasey |
| Green needlegrass | *Stipa viridula* Trin. |
| | **Forbs** |
| Western yarrow | *Achillea lanulosa* Nutt. |
| Columbia monkshood | *Aconitum columbianum* Nutt. |
| Orange agoseris | *Agoseris aurantiaca* (Hook.) Greene |
| Pale agoseris | *Agoseris glauca* (Pursh) Raf. |
| Tapertip onion | *Allium acuminatum* Hook. |
| Nodding onion | *Allium cernuum* Roth |
| Geyer onion | *Allium geyeri* Wats. |
| Redroot amaranth | *Amaranthus retroflexus* L. |
| Giant ragweed | *Ambrosia trifida* L. |
| Rockjasmine | *Androsace septentrionalis* L. |
| Anemone | *Anemone multifida* Poir. |
| Pussytoes | *Antennaria anaphaloides* Rydb. |
| Field pussytoes | *Antennaria neglecta* Greene |
| Rocky Mountain pussytoes | *Antennaria parvifolia* Nutt. |
| ________________ | *Aralia nudicaulis* L. |
| Fendler sandwort | *Arenaria fendleri* Gray |
| Leafy arnica | *Arnica chamissonis* Less. |
| Heartleaf arnica | *Arnica cordifolia* Hook. |
| Sagewort wormwood | *Artemisia campestris* L. |
| Louisiana sagebrush | *Artemisia ludoviciana* Nutt. |
| Siskiyou aster | *Aster hesperius* Gray |
| Porters aster | *Aster porteri* Gray |
| Milkvetch | *Astragalus adsurgens* Pall. |
| Purple milkvetch | *Astragalus agrestis* G. Don |
| Alpine milkvetch | *Astragalus alpinus* L. |
| Milkvetch | *Astragalus miser* Hook. |
| Milkvetch | *Astragalus parryi* Gray |
| Plantainleaf kittentails | *Besseya plantaginea* (Benth.) Rydb. |
| ________________ | *Brickellia grandiflora* (Hook.) Nutt. |
| Gunnison mariposa | *Calochortus gunnissonii* Wats. |
| Marshmarigold | *Caltha leptosepala* DC. |
| Bluebell | *Campanula rotundifolia* L. |
| Wholeleaf paintedcup | *Castilleja integra* Gray |
| Sulfur paintedcup | *Castilleja septentrionalis* Lindl. |
| Starry cerastium | *Cerastium arvense* L. |
| ________________ | *Cerastium vulgatum* L. |
| Douglas chaenactis | *Chaenactis douglasii* H. & A. |
| ________________ | *Chamaerhodos nuttallii* (T. & G.) Pickering |
| Lambsquarters goosefoot | *Chenopodium album* L. |
| Blite goosefoot | *Chenopodium capitatum* (L.) Asch. |
| Slimleaf goosefoot | *Chenopodium leptophyllum* Nutt. |
| Common pipsissewa | *Chimaphila umbellata* (L.) Bart. |
| Goldaster | *Chrysopsis fulcrata* Greene |
| Hairy goldaster | *Chrysopsis villosa* var. *foliosa* (Nutt.) D.C. Eat. |
| European glorybind | *Convolvulus arvensis* L. |
| Spotted coralroot | *Corallorhiza maculata* Raf. |

| | |
|---|---|
| Early coralroot | *Corallorhiza trifida* Chat. |
| Golden corydalis | *Corydalis aurea* Willd. |
| Dandelion hawksbeard | *Crepis runcinata* (James) T. & G. |
| Cryptantha | *Cryptantha thyrsiflora* (Greene) Pays. |
| Cryptantha | *Cryptantha virgata* (Porter) Pays. |
| Branched larkspur | *Delphinium ramosum* Rydb. |
| Darkthroat shootingstar | *Dodecatheon pulchellum* (Raf.) Merr. |
| Field horsetail | *Equisetum arvense* L. |
| Scouring rush | *Equisetum hyemale* L. |
| Smooth horsetail | *Equisetum laevigatum* A. Br. |
| Fernleaf fleabane | *Erigeron compositus* Pursh |
| Trailing fleabane | *Erigeron flagellaris* A. Gray |
| Oregon fleabane | *Erigeron speciosus* (Lindl.) DC. |
| Threenerve fleabane | *Erigeron subtrinervis* Rydb. |
| Fleabane | *Erigeron vetensis* Rydb. |
| Fireweed | *Epilobium angustifolium* L. |
| Wing eriogonum | *Erigonum alatum* Torr. |
| Robust euphorbia | *Euphorbia robusta* (Engelm.) Small |
| Thymeleaf euphorbia | *Euphorbia serpyllifolia* Pers. |
| European strawberry | *Fragaria vesca americana* (Porter) Britt. |
| Wild strawberry | *Fragaria ovalis* (Lehm.) Rydb. |
| Bursage | *Frasera speciosa* Griseb. |
| Northern bedstraw | *Galium boreale* L. |
| Sweetscented bedstraw | *Galium triflorum* Michx. |
| Annual gentian | *Gentiana amarella* L. |
| Fremont geranium | *Geranium fremontii* Torr. |
| Parry geranium | *Geranium parryi* (Engelm.) Heller |
| Richardson geranium | *Geranium richardsonii* Fisch. & Trautv. |
| Allepo avens | *Geum aleppicum* Jacq. |
| Avens | *Geum triflorum* Pursh |
| Skyrocket gilia | *Gilia aggregata* (Pursh) Spreng. |
| Sticky gilia | *Gilia calcarea* Jones |
| Western rattlesnake plantain | *Goodyera oblongifolia* Raf. |
| Creeping rattlesnake plantain | *Goodyera repens* (L.) R. Br. |
| Northern green habenaria | *Habenaria hyperborea* (L.) R. Br. |
| Parry goldenweed | *Haplopappus parryi* Gray |
| Parry helianthella | *Helianthella parryi* Gray |
| Common sunflower | *Helianthus annuus* L. |
| Prairie sunflower | *Helianthus petiolaris* Nutt. |
| | *Helianthus pumilus* Nutt. |
| Common cowparsnip | *Heracleum lanatum* Michx. |
| Littleleaf alumroot | *Heuchera parvifolia* Nutt. |
| Hawkweed | *Hieracium fendleri* Sch.-Bip. |
| Wax currant | *Hymenoxys acaulis* (Pursh) Parker |
| Chicory lettuce | *Lactuca pulchella* (Prush) DC. |
| Stickseed | *Lappula redowskii* (Hornem.) Greene |
| Prairie pepperweed | *Lepidium densiflorum* Schrad. |
| Low bladderpod | *Lesquerella montana* (Gray) Wats. |
| Porter ligusticum | *Ligusticum porteri* C. & R. |
| Butter-and-eggs toadflax | *Linaria vulgaris* Mill. |
| Twinflower | *Linnaea borealis* L. |
| Lewis flax | *Linum lewisii* Pursh |
| Manyflower gromwell | *Lithospermum multiflorum* Torr. |
| Silvery lupine | *Lupinus argenteus* Pursh |
| Lodgepole lupine | *Lupinus parviflorus* Nutt. |
| Drummond campion campion | *Lychnis drummondii* (Hook.) Wats. |
| Rush skeletonplant | *Lygodesmia juncea* (Pursh) D. Don |
| | *Machaeranthera pattersonii* (Gray) Greene |
| Yellow sweetclover | *Melilotus officinalis* (L.) Lam. |
| Desert mentzelia | *Mentzelia multiflora* (Nutt.) Gray |
| Lanceleaf bluebells | *Mertensia lanceolata* (Pursh) A. DC. |
| Common monkeyflower | *Mimulus guttatus* DC. |

| | |
|---|---|
| Evening primrose | *Oenothera coronopifolia* T. & G. |
| Broomrape | *Orobanche fasciculata* Nutt. |
| Yellow owlclover | *Orthocarpus luteus* Nutt. |
| Bluntseed sweetroot | *Osmorhiza depauperata* Phil. |
| Crazyweed | *Oxytropis multiceps* Nutt. |
| Lambert crazyweed | *Oxytropis lambertii* Pursh |
| Early pedicularis | *Pedicularis canadensis* L. |
| Grays pedicularis | *Pedicularis grayi* Nels. |
| Elephanthead pedicularis | *Pedicularis groenlandica* Retz. |
| Crandall penstemon | *Penstemon crandallii* A. Nels. |
| Sidebells penstemon | *Penstemon secundiflorus* Benth. |
| Oneside penstemon | *Penstemon unilateralis* Rydb. |
| Green penstemon | *Penstemon virens* Pennell |
| Wandbloom penstemon | *Penstemon virgatus* Gray |
| | *Phacelia denticulata* Osterch. |
| | *Phacelia heterophylla* Pursh |
| | *Phacelia neomexicana* Torr. |
| Downy groundcherry | *Physalis pubescens* L. |
| Varileaf cinquefoil | *Potentilla diversifolia* Lehm. |
| Bigflower cinquefoil | *Potentilla fissa* Nutt. |
| Gland cinquefoil | *Potentilla glandulosa* Lindl. |
| Northwest cinquefoil | *Potentilla gracilis* Hook. |
| Horse cinquefoil | *Potentilla hippiana* Lehm. |
| Pennsylvania cinquefoil | *Potentilla pensylvanica* L. |
| Prostrate knotweed | *Polygonum aviculare* L. |
| | *Polygonum bistortoides* Pursh |
| Dullseed cornbind | *Polygonum convolvulus* L. |
| | *Pseudocymopteris montanus* (Gray) C. & R. |
| Woodland pinedrops | *Pterospera andromedea* Nutt. |
| Alpine pyrola | *Pyrola asarifolia* Michx. |
| | *Pyrola chlorantha* Swartz |
| Snowline pyrola | *Pyrola minor* L. |
| Sidebells pyrola | *Pyrola secunda* L. |
| | *Pyrola uniflora* L. |
| Littleleaf buttercup | *Ranunculus abortivus* L. |
| Shore buttercup | *Ranunculus cardiophyllus* Hook. |
| | *Ranunculus macounii* Britt. |
| Blackeyedsusan | *Rudbeckia hirta* L. |
| Western dock | *Rumex occidentalis* Wats. |
| Yellowdot saxifrage | *Saxifraga bronchialis* L. |
| Brittons scullcap | *Scutellaria brittonii* Porter |
| Stonecrop | *Sedum rhodanthum* Gray |
| | *Sedum stenopetalum* Pursh |
| Desert groundsel | *Senecio eremophilus* Richards |
| Fendler groundsel | *Senecio fendleri* Gray |
| Lambstongue groundsel | *Senecio integerrimus* Nutt. |
| | *Senecio pudicus* Greene |
| | *Senecio tridenticulatus* Rydb. |
| | *Senecio werneriaefolius* Gray |
| | *Senecio wootonii* Greene |
| Starry solomonplume | *Smilacina stellata* (L.) Desf. |
| Black nightshade | *Solanum nigrum* L. |
| Cutleaf nightshade | *Solanum triflorum* Nutt. |
| | *Solidago decumbens* Greene |
| | *Solidago multiradiata* Ait. |
| Baby goldenrod | *Solidago nana* Nutt. |
| marsh betony | *Stachys palustris* L. |
| Claspleaf twistedstalk | *Streptopus amplexifolius* (L.) DC. |
| Alpinebog swertia | *Swertia perennis* L. |
| Common dandelion | *Taraxacum officinale* Weber |
| Meadowrue | *Thalictrum fendleri* Gray |
| Pennycress | *Thlaspi alpestre* L. |

| | |
|---|---|
| Field pennycress | *Thlaspi arvense* L. |
| Salsify | *Tragopogon dubius* Scop. |
| Vegetable-oyster salsify | *Tragopogon parvifolius* L. |
| Alsike clover | *Trifolium hybridum* L. |
| White clover | *Trifolium repens* L. |
| Valerian | *Valeriana capitata* Link |
| Edible valerian | *Valeriana edulis* Nutt. |
| Golden crownbeard | *Verbesina encelioides* (Cav.) B. & H. |
| Water speedwell | *Veronica anagallis-aquatica* L. |
| Hook violet | *Viola adunca* J. E. Sm. |
| Canada violet | *Viola canadensis* L. |
| Nuttall violet | *Viola nuttallii* Pursh |
| ________________ | *Viola renifolia* Gray |
| Mountain deathcamas | *Zigadenus elegans* Pursh |

**Shrubs**

| | |
|---|---|
| Rocky Mountain maple | *Acer glabrum* Torr. |
| Thinleaf alder | *Alnus tenuifolia* Nutt. |
| Saskatoon serviceberry | *Amelanchier alnifolia* Nutt. |
| Southwestern dwarf mistletoe | *Arceuthobium vaginatum* (Willd.) Presl. |
| Bearberry | *Arctostaphylos uva-ursi* (L.) Spreng. |
| Fringed sagebrush | *Artemisia frigida* Willd. |
| Creeping mahonia | *Berberis repens* Lindl. |
| Water birch | *Betula occidentalis* Hook. |
| True mountainmahogany | *Cercocarpus montanus* Raf. |
| Rabbitbrush | *Chrysothamus viscidiflorus* H. & C. |
| Rocky Mountain clematis | *Clematis pseudoalpina* (Kuntze) A. Nels. |
| Bunchberry dogwood | *Cornus canadensis* L. |
| Red-osier dogwood | *Cornus stolonifera* Michx. |
| Bush rockspirea | *Holodiscus dumosus* (Nutt.) Heller |
| Cliff jamesia | *Jamesia americana* T. & G. |
| Common juniper | *Juniperus communis* L. |
| Bearberry honeysuckle | *Lonicera involucrata* (Richards) Banks |
| Mountain ninebark | *Physocarpus monogynus* (Torr.) Coult. |
| Shrubby cinquefoil | *Potentilla fruticosa* L. |
| Common chokecherry | *Prunus virginiana* L. |
| Skunkbush sumac | *Rhus trilobata* Nutt. |
| Wax currant | *Ribes cereum* Dougl. |
| Whitestem gooseberry | *Ribes inerme* Rydb. |
| Gooseberry currant | *Ribes montigenum* McClat. |
| Arkansas rose | *Rosa arkansana* Porter |
| Boulder raspberry | *Rubus deliciosus* Torr. |
| ________________ | *Rubus pubescens* Raf. |
| ________________ | *Rubus strigosus* Michx. |
| Coyote willow | *Salix exigua* Nutt. |
| Pussy willow | *Salix discolor* Muhl. |
| Elderberry | *Sambucus racemosa* L. |
| Common snowberry | *Symphoricarpos albus* (L.) Blake |
| Rocky Mountain whortleberry | *Vaccinium myrtillus* L. |
| Small soapweed | *Yucca glauca* Nutt. |

**Trees**

| | |
|---|---|
| Engelmann spruce | *Picea engelmannii* Parry |
| Blue spruce | *Picea pungens* Engelm. |
| Lodgepole pine | *Pinus contorta* Dougl. |
| Pinyon | *Pinus edulis* Engelm. |
| Limber pine | *Pinus flexilis* James |
| Ponderosa pine | *Pinus ponderosa* Laws. |
| Quaking aspen | *Populus tremuloides* Michx. |
| Douglas-fir | *Pseudotsuga menziesii* (Mirb.) Franco |

*[1]Plant names mentioned in publications and reports from the Manitou Experimental Forest.*



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Gary, Howard L. 1985. A summary of research at the Manitou Experimental Forest in Colorado, 1937–1983. USDA Forest Service General Technical Report RM-116, 24 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins. Colo.

Results of selected studies for range, watershed, timber and wildlife management research are summarized to provide land managers, land-use planners, and land-use researchers with information to help evaluate consequences of land management practices in the Colorado Front Range ponderosa pine zone.

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Results of selected studies for range, watershed, timber and wildlife management research are summarized to provide land managers, land-use planners, and land-use researchers with information to help evaluate consequences of land management practices in the Colorado Front Range ponderosa pine zone.

**Keywords:** Watershed, timber management research, range

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

# Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526